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13. ABSTRACT (Maximum 200 words) Research areas included standby redundancy policies, redundancy allocations in series and parallel systems, goodness-of-fit tests for censored data, autopsy models, nonparametric methods for imperfect repair, inference for systems operating in different environments, and dynamic reliability models. Twenty-nine technical reports were written in the period and twenty-six papers were published in the period.				
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FINAL SUMMARY REPORT

for AFOSR Grant 91-0048

October 1, 1990 through September 30, 1994

**Research in the Statistical Aspects of
Reliability, Availability, and Maintainability**

Approved:

Myles Hollander
Professor and Principal InvestigatorDuane Meeter
Chairman, Department of Statistics

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1. Summary. During the four-year period (October 1, 1990 - September 30, 1994) of Grant AFOSR 91-0048 Statistical Aspects of Reliability, Availability, and Maintainability, Co-Principal Investigators Myles Hollander and Frank Proschan and other researchers partially supported under the Grant, produced 29 technical reports, 26 published papers, and one published book. Myles Hollander and Frank Proschan were Co-Principal Investigators from October 1, 1990 - December 31, 1992. In December, 1992, Frank Proschan retired and Myles Hollander was Principal Investigator from January 1, 1993 - September 30, 1994.

Research topics covered included standby redundancy policies for series systems, redundancy allocations in series and parallel systems, goodness-of-fit tests for censored data, testing the minimal repair assumption in an imperfect repair model, multiple dependent competing risk models, reliability models involving mutual censorship of component lifelengths, convex ordering with applications to reliability, autopsy models in reliability, redundancy, importance and allocation of spares in coherent systems, nonparametric methods for imperfect repair models, wavelet methods for curve estimation, models and inference for systems operating in different environments, stochastic inequalities in system reliability, dynamic models for reliability, nonparametric techniques for analyzing survey data arising in Air Force Quality Management surveys, and dependence properties of order statistics. Consulting was done with Air Force personnel at Eglin Air Force Base, Ft. Walton Beach, Florida and Maxwell Air Force Base, Montgomery, Alabama.

The Reliability Center was active during the period with visitors including Edsel Peña, Bowling Green State University, Ramesh Korwar, University of Massachusetts, Philip Boland, University College, Belfield Dublin, Ireland, Emad El-Newehi, University of Illinois at Chicago, Kumar Joag-Dev, University of Illinois at Urbana, Ghagik Tsaturgan, Terevan Polytechnic Institute, Teryan, Armenia (former Soviet Union), T.E.S. Raghaven, University of Illinois, Chicago, Frank Samaniego, University of California, Davis, and Yung Tong, Georgia Institute of Technology. Many of the visitors, including P. Boland, E. Peña, E. El-Newehi, and K. Joag-Dev made multiple visits.

2. Technical Reports Produced Under Grant AFOSR 91-0048 (October 1, 1990 - September 30, 1994)

A Mixed Limit Theorem for Stable Random Fields

by T. V. Kurien and Jayaram Sethuraman

AFOSR Technical Report No. 91-251, January 1991

Singularities in Gaussian Random Fields

by T. V. Kurien and Jayaram Sethuraman

AFOSR Technical Report No. 91-256, January 1991

Max-Infinite Divisibility and Multivariate Total Positivity

by Abdulhamid A. Alzaid and Frank Proschan

AFOSR Technical Report No. 91-252, January 1991

Standby Redundancy Policies for Series Systems

by Philip J. Boland, Frank Proschan, and Y. L. Tong

AFOSR Technical Report No. 91-253, January 1991

Estimating and Modeling Gene Flow for a Spatially Distributed Species

by T. Burr and T. V. Kurien

AFOSR Technical Report No. 91-255, January 1991

Stochastic Order for Redundancy Allocations in Series and Parallel Systems by Philip J. Boland, Emad El-Newehi and Frank Proschan
AFOSR Technical Report No. 91-254, January 1991

Some Classes of Nonparametric Goodness-of-Fit Tests for Censored Data, Part I: Simple Null Hypothesis Case
by Myles Hollander and Edsel Peña
AFOSR Technical Report No. 91-258, February 1991

On the Analysis of Grouped Survival Data Using Cumulative Occurrence/Exposure Rates
by Ian W. McKeague and Mei-Jie Zhang
AFOSR Technical Report No. 91-257, March 1991

A Stochastic Ordering of Partial Sums of Independent Random Variables and Some Random Processes
by Philip J. Boland, Frank Proschan, and Y. L. Tong
AFOSR Technical Report No. 91-259, March 1991

Choosing The Resampling Scheme When Bootstrapping: A Case Study in Reliability
by Yuang-Chin Chiang and Hani Doss
AFOSR Technical Report No. 91-260, April 1991

Inequalities for the Parameters $\lambda(F)$, $\mu(F)$ with Applications in Nonparametric Statistics
by C. Dorado and Myles Hollander
AFOSR Technical Report 91-262, August 1991

Identification of Nonlinear Times Series From First Order Cumulative Characteristics
by Ian W. McKeague and Mei-Jie Zhang
AFOSR Technical Report 91-261, August 1991

An Elementary Approach To Weak Convergence For Quantile Processes, With Applications To Censored Survival Data
by Hani Doss and Richard D. Gill
AFOSR Technical Report 91-263, August 1991

Testing the Minimal Repair Assumption in an Imperfect Repair Model
by Myles Hollander, B. Presnell, and Jayaram Sethuraman
AFOSR Technical Report 91-266, September 1991

A Comparison of Various Estimators in Reliability Models Involving Mutual Censorship of Component Lifetimes
by Robin Antoine, Hani Doss, and Myles Hollander
AFOSR Technical Report 91-265, September 1991

Stochastic Order in System Reliability Theory
by Philip J. Boland and Frank Proschan
AFOSR Technical Report 91-268, August 1991

Applications of the Hazard Rate Ordering in Reliability and Order Statistics

by Philip J. Boland, Emad El-Newehi and Frank Proschan
AFOSR Technical Report No. 91-269, September 1991

On Identifiability in the Autopsy Model of Reliability Theory

by Robin Antoine, Hani Doss and Myles Hollander
AFOSR Technical Report No. 91-267, October 1991

A General Composition Theorem and its Applications to Certain Partial Orderings of Distributions

by Kumar Joag-Dev, Subhash Kochar and Frank Proschan
AFOSR Technical Report No. 91-270, February 1992

Wavelet Methods for Curve Estimation

by A. Antoniadis, G. Gregoire, and I. W. McKeague
AFOSR Technical Report No. 91-271, July 1992

Some Tests for Comparing Cause-Specific Hazard Rates

by E.A.A. Aly, S. C. Kochar, and I. W. McKeague
AFOSR Technical Report No. 91-272, July 1992

Schur Properties of Convolutions of Exponential and Geometric Random Variables

by P. J. Boland, E. El-Newehi, and F. Proschan
AFOSR Technical Report No. 91-273, July 1992

Some Recent Applications of Stochastic Inequalities in System Reliability

by P. J. Boland, F. Proschan, and Y. L. Tong
AFOSR Technical Report No. 91-274, September 1992

Transformations of Gaussian Random Fields and a Test for Independence of a Survival Time from a Covariate

by I. W. McKeague, A. M. Nikabadze, and Y. Sun
AFOSR Technical Report No. 91-275, November, 1992

Models and Inference for Series Systems Operating Under Different Environments

by Edsel Peña and Myles Hollander
AFOSR Technical Report No. 91-276, December, 1992

A Partly Parametric Additive Risk Model

by I. W. McKeague and P. Sasieni
AFOSR Technical Report No. 91-277, January, 1993

Bivariate Dependence Properties of Order Statistics

by P. J. Boland, M. Hollander, K. Joag-Dev, and S. Kochar
AFOSR Technical Report No. 91-278, January, 1994

Dynamic Reliability Models Using Conditional Proportional Hazards

by Myles Hollander and Edsel Peña
AFOSR Technical Report No. 91-279, August, 1994

Dynamic Reliability Models

by Myles Hollander and Edsel Peña

AFOSR Technical Report No. 91-280, September, 1994

3. Papers Published Under Grant AFOSR 91-0048 (October 1, 1990 - September 30, 1994).

Inference for a Nonlinear Counting Process Regression Model

by Ian McKeague and Klaus J. Utikal. *The Annals of Statistics*, **18**, pp. 1172-1187, (1990)

Identifying Nonlinear Covariate Effects in Semimartingales

Regression Models by Ian W. McKeague and Klaus J. Utikal
Probab. Th. Rel. Fields, **87**, pp. 1-25, (1990)

Independence of the Time and Cause of Failure in the Multiple

Dependent Competing Risks Model by Subhash C. Kocher and Frank Proschan. *Statistica Sinica*, **1**, pp. 295-299, (1991)

Laplace Ordering and its Applications by Abdulhamid Alzaid, Jee Soo Kim, and Frank Proschan, *J. Appl. Prob.*, **28**, pp. 116-130, (1991)

Stochastic Order for Inspection and Repair Policies by Philip J. Boland, Emad El-Newehi, and Frank Proschan. *The Annals of Applied Probability*, Vol. 1, No. 2, pp. 207-218, (1991)

Some Majorization Inequalities for Functions of Exchangeable

Random Variables by Philip J. Boland, Frank Proschan, and Y. L. Tong.
Topics in Statistical Dependence, Ed. by H. W. Block, A. R. Sampson, and T. H. Savits, IMS Lecture Notes - Monograph 16, pp. 85-91, (1991)

Information, Censoring, and Dependence by Myles Hollander, Frank Proschan, and James Sconing. *Topics in Statistical Dependence*, Ed. by H. W. Block, A. R. Sampson, and T. H. Savits, IMS Lecture Notes - Monograph 16, pp. 257-268, (1991)

Convex-Ordering Among Functions, with Applications to Reliability and

Mathematical Statistics by Wai Chan, Frank Proschan, and Jayaram Sethuraman.
Topics in Statistical Dependence. Ed. by H. W. Block, A. R. Sampson, and T. H. Savits, IMS Lecture Notes - Monograph 16, pp. 121-134, (1991)

Redundancy Importance and Allocation of Spares in Coherent Systems

by Philip J. Boland, Emad El-Newehi and Frank Proschan
Journal of Statistical Planning and Inference, **29**, pp. 55-66, (1991)

Dispersivity and Stochastic Majorization

by Abdulhamid A. Alzaid
Statistics & Probability Letters, **13**, pp. 275-278, (1992)

Birthday Problem with Unlike Probabilities

by Kumar Joag-Dev and Frank Proschan
American Mathematical Monthly, **99**, No. 1, pp. 10-12, (1992)

Stochastic Order for Redundancy Allocations in Series and Parallel Systems

by Philip J. Boland, Emad El-Newehi and Frank Proschan
Adv. Appl. Prob., **24**, pp. 161-171, (1992)

Classes of Nonparametric Goodness-of-Fit Tests for Censored Data: Simple Null Hypothesis Case

by Myles Hollander and Edsel A. Peña
Nonparametric Statistics and Related Topics, pp. 97-118, (1992)

A Chi-Squared Goodness-of-Fit Test for Randomly Censored Data

by Myles Hollander and Edsel Peña
Journal of the American Statistical Association, **87**, No. 418, pp. 458-463, (1992)

Nonparametric Models for Imperfect Repair Models

by Myles Hollander, Brett Presnell and Jayaram Sethuraman
Annals of Statistics, **20**, pp. 879-896, (1992)

Nonlinear Time Series Analysis via Cumulative Regressograms

by I. W. McKeague and Mei-Jie Zhang
 Proceedings of the Thirty-Seventh Conference on the Design of Experiments in Army Development and Testing 217-224, (1992)

A Stochastic Ordering of Partial Sums of Independent Random Variables and Some Random Processes

by P. J. Boland, F. Proschan, and Y. L. Tong
Journal of Applied Probability, **29**, 643-654 (1992)

Inequalities for the Parameters $\lambda(F)$, $\mu(F)$ with Applications in Nonparametrics Statistics

by C. Dorado and M. Hollander
 In: *Stochastic Inequalities* (edited by M. Shaked and Y. L. Tong) 50-65, Institute of Mathematical Statistics Monograph Series Vol. 22, (1993)

A Comparison of Various Estimators in Reliability Models Involving Mutual Censorship of Component Lifetimes

by R. Antoine, H. Doss, and M. Hollander
 In: *Advances in Reliability* (edited by A. P. Basu) 1-20, North Holland

Some Recent Applications of Stochastic Inequalities in System Reliability Theory

by P. J. Boland, F. Proschan, and Y. L. Tong
 In: *Advances in Reliability* (edited by A. P. Basu) 19-41, North Holland

Discussion of T. Hastie and R. Tibshirani's paper "Varying-Coefficient Models"

by I. W. McKeague and P. Sasieni
Journal of the Royal Statistical Society B **55**, 786-787 (1993)

On Identifiability in the Autopsy Model of Reliability Theory

by R. Antoine, H. Doss, and M. Hollander
Journal of Applied Probability **30**, 913-930, (1993)

Testing the Minimal Repair Assumption in an Imperfect Repair Model
by B. Presnell, M. Hollander, and J. Sethuraman
Journal of the American Statistical Association 89, 289-297, (1994)

Applications of the Hazard Rate Ordering in Reliability and Order Statistics
by P. J. Boland, E. El-Newehi, and F. Proschan
Journal of Applied Probability 31, 180-192, (1994)

A Partly Parametric Additive Risk Model
by I. W. McKeague and P. D. Sasieni
Biometrika 81, 501-514, (1994)

Identification of Nonlinear Time Series from First Order Cumulative Characteristics
by I. W. McKeague and M. Zhang
Annals of Statistics 22, 495-514, (1994)

4. Book Published Under AFOSR 91-0048 (October 1, 1990 - September 30, 1994)

Convex Functions, Partial Orderings, and Statistical Applications by Josip E. Pečarić, Frank Proschan, and Y. L. Tong. *Academic Press*, New York, 1992.

5. Awards and Honors under AFOSR 91-0048 (October 1, 1990 - September 30, 1994)

Frank Proschan and colleague Richard E. Barlow, University of California at Berkeley, jointly received the 1991 von Neumann Award for their fundamental research in reliability theory and practice. The award was presented by the Operations Research Society of America and The Institute of Management Sciences at their Annual Joint Meeting in Nashville, Tennessee, May, 1991.

Myles Hollander served as Editor-Elect of the Journal of the American Statistical Association, Theory and Methods Section, January 1, 1993 - December 31, 1993. In January, 1994 he began a three-year term as Editor.